University of Groningen

The photophysics of solution processable semiconductors for applications in optoelectronic devices

Abdu-Aguye, Mustapha

DOI:

[10.33612/diss.111696164](https://doi.org/10.33612/diss.111696164)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version

Publisher's PDF, also known as Version of record

Publication date:

2020

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Abdu-Aguye, M. (2020). *The photophysics of solution processable semiconductors for applications in optoelectronic devices*. [Thesis fully internal (DIV), University of Groningen]. University of Groningen. <https://doi.org/10.33612/diss.111696164>

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

The photophysics of solution-processable semiconductors for applications in optoelectronic devices

Mustapha Tisan Abdu-Aguye

Netherlands Organisation
for Scientific Research

PHOTOPHYSICS &
OPTO-ELECTRONICS

university of
 groningen

faculty of science
and engineering

zernike institute for
advanced materials

Zernike Institute PhD thesis series 2020-03

ISSN: 1570-1530

ISBN: 978-94-034-2288-6 (print version)

ISBN: 978-94-034-2287-9 (electronic version)

The work described in this thesis was performed in the Photophysics and Optoelectronics research group of the Zernike Institute for Advanced Materials at the University of Groningen, The Netherlands. The research was funded by the Netherlands Organisation for Scientific Research, NWO as part of the *Next Generation Organic Photovoltaics* Focus Group (Program Nr. 130) participating in the Dutch Institute for Fundamental Energy Research (DIFFER).

Font: Garamond

Cover Design: Collaboration with Girolamo Sferrazza Papa (www.giросcience.com)

Printed by: Ipskamp Printers (www.proefschriften.net)

university of
 groningen

The photophysics of solution-processable semiconductors for applications in optoelectronic devices

PhD Thesis

To obtain the degree of PhD at the
University of Groningen
on the authority of the
Rector Magnificus Prof. C. Wijmenga
and in accordance with
the decision by the College of Deans.

This thesis will be defended in public on

Monday 27 January 2020 at 11.00 hours

by

Mustapha Tisan Abdu-Aguye

born on 30 August 1988
in Zaria, Nigeria

Supervisors

Prof. M. A. Loi

Prof. J. C. Hummelen

Assessment Committee

Prof. R. M. Hildner

Prof. A. A. Mura

Prof. R. L. Brutchey

Dedicated to my Parents

Contents

Chapter 1	1
1.1 Introduction	2
1.2 Solar Cells	4
1.3 Solution Processable Semiconductors	6
1.4 Polymers	7
1.4.1 Semiconducting Polymers	7
1.4.2 Ferroelectric Polymers	10
1.5 Semiconducting Nanocrystals, Or Quantum Dots	11
1.6 Hybrid Perovskites	14
1.7 Methods	15
1.7.1 Absorbance Spectroscopy	16
1.7.2 Photoluminescence Spectroscopy	18
1.7.3 Solar Cell Current-Voltage Characteristics	19
1.8 Outline	21
References	23
Chapter 2	27
2.1 Introduction	28
2.2 Experimental	29
2.2.1 Materials	29
2.2.2 Film Preparation	31
2.2.3 UV-Vis Absorption Spectroscopy	31
2.2.4 Photoluminescence Spectroscopy	31

2.3	Results and Discussion.....	32
2.4	Conclusion	39
	References.....	40
Chapter 3	.....	43
3.1	Introduction.....	44
3.2	Experimental.....	45
3.2.1	Materials.....	45
3.2.2	Thin Film Preparation	46
3.2.3	Absorption Spectroscopy.....	47
3.2.4	Steady State & Time Resolved Photoluminescence Spectroscopy....	47
3.2.5	Atomic Force Microscopy	48
3.2.6	Grazing Incidence Wide-Angle X-ray Scattering	48
3.2.7	Solar Cell Characterization.....	48
3.2.8	Impedance Spectroscopy	49
3.3	Results and Discussion.....	49
3.3.1	UV-VIS and Photoluminescence Spectroscopy of the P3HT- <i>b</i> -P(VDF-TrFE)- <i>b</i> -P3HT triblock copolymer	49
3.3.2	Impedance Spectroscopy	51
3.3.3	Ternary blends of P3HT- <i>b</i> -P(VDF-TrFE)- <i>b</i> -P3HT: P3HT:PCBM.....	52
3.3.4	Structure and Morphology of ternary blends.....	54
3.3.5	The role of LiF in copolymer-containing devices	57
3.3.6	Light Intensity dependent measurements, poling measurements, and UV-photostability.....	58
3.4	Conclusion	59
3.5	Supporting Information.....	60
	References.....	61
Chapter 4	.....	63
4.1	The effect of microstructure on trap-assisted recombination and light soaking.....	64
4.1.1	Introduction	64

4.1.2	Morphology of films of mixed halide perovskites	66
4.1.3	Photovoltaic Performance	67
4.1.2	Light intensity dependent J_{sc} and V_{oc} measurements.....	69
4.1.3	Spectroscopic Studies	71
4.1.4	Conclusion.....	73
4.2	Enhancing the performance of perovskite solar cells using a high- ϵ_r fullerene derivative as electron extraction material	73
4.2.1	Introduction	73
4.2.2	Photovoltaic device performance & morphology.....	75
4.2.3	The origin of light-soaking: trap-assisted recombination.....	77
4.2.4	Mechanism of trap-assisted recombination suppression	80
4.2.5	Conclusion.....	82
4.3	Experimental.....	82
4.3.1	Materials	82
4.3.2	Device Fabrication	83
4.3.3	Solar Cell Characterization.....	83
4.3.4	Photoluminescence Measurements	83
4.3.5	Morphological Characterization.....	83
	References.....	85
Chapter 5	.....	89
5.1	Introduction	90
5.2	Experimental.....	92
5.2.1	Ink Preparation	92
5.2.2	Absorption Spectroscopy.....	92
5.2.3	Photoluminescence (PL) Spectroscopy	92
5.2.4	Field Effect Transistor (FET) fabrication and measurement.....	93
5.3	Results and Discussion.....	93
5.4	Conclusion	101
5.5	Supporting Information.....	102
	References.....	105
Summary	.....	109

Samenvatting.....	113
Acknowledgements	117
List of Publications	125
Curriculum Vitae	129